LA-UR- 92-3150

Title:

Data Acquisition System for the Large Scintillating Neutrino Detector at Los Alamos

LA-UR--92-3150

DE93 000700

Author(s):

G. Anderson, I. Cohen, B Homann, D. Smith, W. Strossman, G. J. VanDalen, L. S. Weaver, D. Evans, W. Vernon, A. Band, R. Burman, T. Chang, F. Federspiel, W. Foreman, S. Gomulka, G. Hart, T. Kozlowski, W. C. Louis, J. Margulies, A. Nuanes, V. Sandberg, T. N. Thompson, D. H. White, D. Whitehouse

Submitted to:

The Conference on Computing in High Energy Physics 1992, September 21-25, 1992, Annecy, France

Los Alamos
NATIONAL LABORATORY

Data Acquisition System for the Large Scintillating Neutrino Detector at Los Alamos

G. Anderson, L. Cohen
Linfield College

B. Homann, D. Smith
Embry-Riddle Aeronautical University

W. Strossman, G. J. VanDalen
University of California, Riverside

L. S. Weaver, D. Evans, W. Vernon
University of California, San Diego

A. Band, R. Bi .an, T. Chang, F. Federspiel, W. Foreman, S. Gomulka, G. Hart, . Kozlowski, W. C. Louis, J. Margulies, A. Nuanes, V. Sandberg, T. N. Thompson, D. H. White, D. Whitehouse
Los Alamos National Laboratory

The data acquisition system for the Large Scintillating Neutrino Detector (LSND) is described. The system collects time and charge information in real time from 1600 photomultiplier tubes and passes the data in intelligent-trigger selected time windows to analysis computers, where events are reconstructed and analyzed as candidates for a variety of neutrino-related physics processes. The system is composed of fourteen VME crates linked to a Silicon Graphics, Inc. "4D/480" multiprocessor computer through multiple, parallel Ethernets, and a collection of contemporary high-performance workstations.

Introduction

Experimental neutrino physics at energies of less than 1 GeV has historically been plagued by low signal to noise ratios; in particular the rate from cosmic rays dominates the signal rate by orders of magnitude. This has forced most experimenters to retreat to low background radiation zones in deep mines and caverns. A new design for an event-driven data acquisition system is described for a detector being built at Los Alamos for a new generation of neutrino oscillation searches. The system described here represents a use of contemporary technology to confront the cosmic-ray rate in a surface neutrino experiment in a novel way. The apparatus consists of a 200 ton volume of dilute liquid scintillator viewed by 1220 photomultiplier tubes (Figure 1) and surrounded by a cosmic-ray veto tank of scintillator viewed by an additional 292 photomultiplier tubes. The detector operates as a combination Čerenkov and scintillation detector to provide tracking and good low-energy resolution.

The system is built in modular VME-based instrumentation. Thirteen VME crates, called "Q-T crates", each contain sixteen photomultiplier-data acquiring "Q-T Cards", trigger data cards, and a 68040-based monoboard computer (e.g., Motorola MVME-167). Each of these crates collects charge and time data for 128 photomultiplier tubes and stores the data at 100 ns intervals in dual-ported memories of sufficient depth to allow the trigger a 200 μs decision period. A fourteenth crate, the trigger crate, selects events of interest and initiates the transfer of Q-T data to local FIFO memories. This trigger contains cards that monitor time-series data on the number of photomultiplier tubes "on" in any 100 ns interval and the total charge detected by all the tubes in the main tank. It uses a system of fast digital comparators and memory stacks to allow past history correlations of events, and a monoboard computer to make trigger decisions and broadcast trigger signals to the Q-T crates. The monoboard computers in the Q-T crates control the VME bus data transfer of the event time-window data in the FIFOs, compensate and compact the data stream, and pipe it to the SGI 4D/480 over several Ethernet cables. The data streams from the fourteen VME crates are brought together and assembled as packages of events by the SGI 4D/480.

Data Acquisition Circuitry

A high-performance integrator and a discriminator-triggered, linearly rising voltage ramp serves each phototube (Figure 2). The integrator has a bandwidth of 1 GHz and an exponential decay constant of about 6 μs. The linearly rising voltage ramp allows fine time information to be acquired with 1 ns granularity. Flash analog to digital convertors (MC10319) present eight-bit digitized values of the integrator output and the voltage ramp at 100 ns intervals to 2048 × 8 bit dual-ported memories (CY7C142-35PC), which record these data at addresses equivalent to the time of occurrence. This system stores in excess of 200 μs of time history for all the phototubes in the experiment. The system also presents summary information to the trigger crate. The trigger decision will be based upon the number of hit phototubes and the total number of photoelectrons within the detector. These signals, combined with event history correlations will allow a trigger decision to be made and appropriate dual-port addresses are broadcast back to the Q-T crates. Upon receipt of a trigger, the Q-T cards will transfer digitized values (typically four) from the dual-ported memories to 2048 × 9 bit FIFO memories (CY7C428-20PC), which are accessible at VME bus locations. This hardware system has the capacity to record a burst of up to 500 events provided the trigger decision is made within 200 μs of the event. (Figure 3.)

The data acquisition circuitry is continually presenting digitized information. Triggering is accomplished by transfering these data to a buffer for later read-out over a VME bus. A burst of 500 events at a rate of approximately 2 MHz can be serviced without difficulty, however, the average data rate is expected to be of the order of 100 Hz.

VME Crate Operation

Each of thirteen VME crates will contain a VME monoboard computer running the VxWorks operating system, sixteen Q-T cards, a card to receive the broadcast trigger signal, and cards to transmit summary information to the trigger system. Since the Q-T cards serve eight phototube signals each, the crates individually deal with up to 128 phototube signals.

The trigger system will cause digitized values of the integrated phototube signals and the associated timing ramps to be transfered from the dual-ported memories into the FIFO memories. An additional FIFO memory in the trigger receiver system will be loaded with the time code of the data collected in the Q-T card FIFOs. The monoboard will poll to determine if the data transfer to the FIFOs has been triggered and initiate a DMA transfer of data across the VME bus into its local memory. The monoboard has the capacity to do a pre-defined set of DMA transfers without processor intervention. Approximately 260 bytes will need to be transfered to the monoboard over the VME per time code of the data recorded in each crate. The data will be transfered four or more times in response to a trigger. During the time when the DMA is being accomplished, the processor can compact and transfer over Ethernet previously acquired events.

The data compaction consists of several parts. Those channels for which there was not sufficient pulse height to cause the discriminator to start a timing ramp are removed from the data stream. The integrated pulse height will be numerically differenced to determine the total charge collected in the 100 ns interval. A set of tabulated computations will be examined to determine the fine time information.

Trigger System

The total number of phototubes with charge sufficient to cause discriminator output and the total charge collected by all phototubes will be available for each 100 ns time interval. Monte Carlo studies show that these two are expected to be strong functions of energy. Fast digital comparators will signal the presence of an event of high enough energy to be an electron with sufficient energy to have been caused by a neutrino event of interest. Other comparators will signal the presence of a lower energy event associated with the 2.2 MeV gamma from neutron capture or the very high energy associated with the presence of a high-energy cosmic ray. Since the possibility exists that a cosmic-ray muon will stop in the apparatus and decay giving an electron with energy in the same range of energy as a neutrino event, the trigger apparatus must correlate these in time with the cosmic-ray signals. If such an electron is found within a few tens of microseconds of a cosmic-ray muon, then the system will trigger the recording of both the cosmic ray and the electron. It is the novel free-running front end and 200 μs depth of the dual-ported memory that enable the trigger to delay the decision to write a muon event to the FIFO's. Thus most cosmic muons are discarded (they are overwritten in the dual ports), while one associated with an electron event that is potentially its decay product is written to tape. Off-line analysis will attempt to correlate these in space. If the location of the cosmic ray is found to be sufficiently distant from the electron, then the electron will continue to be kept in our data as an interesting event.

Event Builder

Four Ethernet connections will connect the VME monoboard computers to an SGI 4D/480; three or four monoboards per Ethernet (Figure 4). (The possibility that CEBAF's CODA will be used to connect these VME computers to the SGI is currently being considered.) The SGI computer will assemble the data and determine the energy of the detected particle, the position and type of the particle. For electrons and high-energy muons, the Čerenkov cone will allow the determination of the direction of travel. The energy is expected to be resolvable to approximately 5% for electrons of 30 MeV or higher and the position to about 10 cm and the direction of travel to about 15°.

Conclusion

Contemporary technology allows the construction of a nearly dead-timeless neutrino detector for use above ground and in close proximity to a high intensity, low energy neutrino beam.

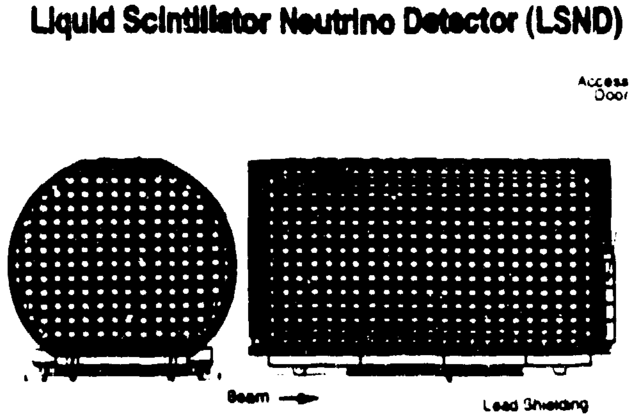

Figure 1. Main detector tank showing placement of photomultiplier tubes.

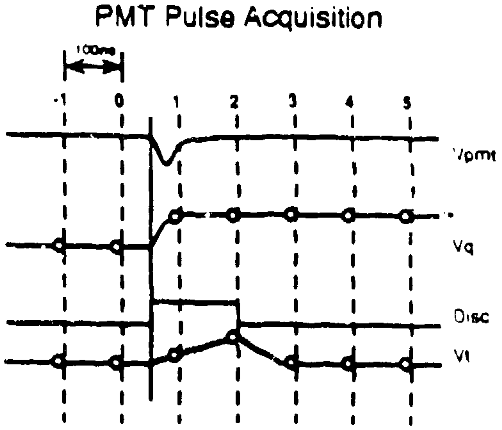

Figure 2. Photomultiplier tube pulse acquisition.

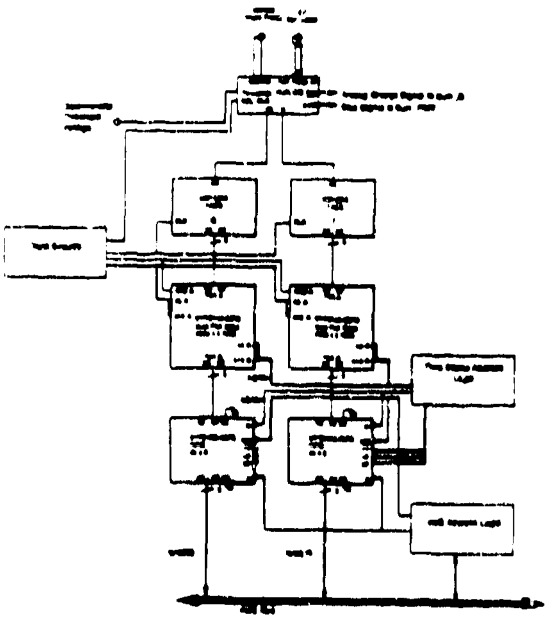

Figure 3. Front-end electronics for a single photomultiplier tube.

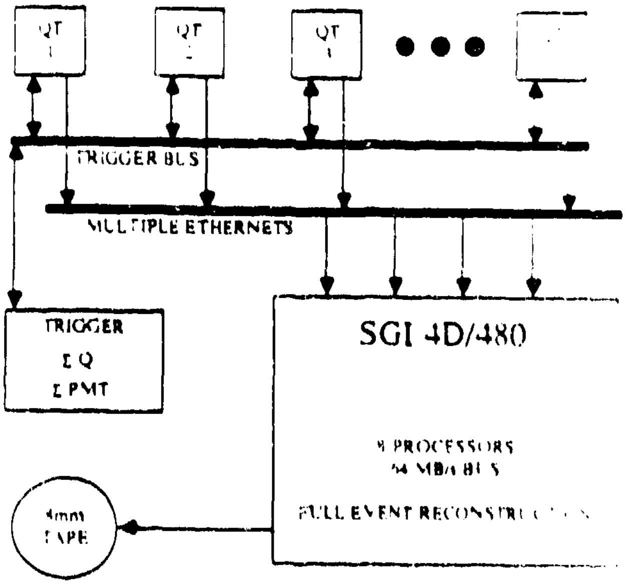

Figure 4. LSND Data Acquisition System.